Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title : Proposal of a spreading method for implementing NG-SUN FSK PHY

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Re : TG4ad Next Generation SUN PHYs

Abstract : This contribution shows the performance simulation results of PFSK over COST207 and IEEE802 channel model, and proposal of a spreading method for implementing NG-SUN FSK PHY to get time diversity gain over the SNR gain.

Purpose: Discussion

Introduction(1/2)

- **A2UICT proposed NG-SUN FSK PHY based on P-FSK modulation scheme in document 15-25-0052-00-04ad .**
  - P-FSK generates 4-dimensional orthogonal signal by combining FSK and PPM while the data rate and signal bandwidth intact.
  - The resulting P-FSK scheme can save 2.7 dB transmission power at the endpoint device, which makes it attractive for NG-SUN PHYs
- **This contribution shows the performance simulation results for P-FSK modulation system over the COST207 urban area channel model and the IEEE802 rural area channel model.**
  - Uncoded & Coded BER vs. Eb/No
  - PER(FER) vs. Eb/No
  - NG-SUN FSK PHY needs to achieve some form of diversity gain in the both channel environments.

Introduction(2/2)

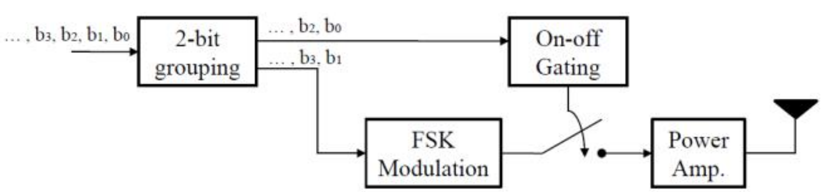
- **Propose a new spreading technique that obtains time diversity gain over SNR gain to improve the performance of NG-SUN FSK PHY.**
  - A2UICT proposed spreading technique to get enhanced sensitivity performance in document 15-25-0053-00-04ad, but this method does not provide sufficient diversity gain.
  - Propose a time diversity technique that Implement the spreading in the form of multiple transmission of a packet and receiver tries to combine the demodulated symbol.

Recap of P-FSK modulation(1/2)

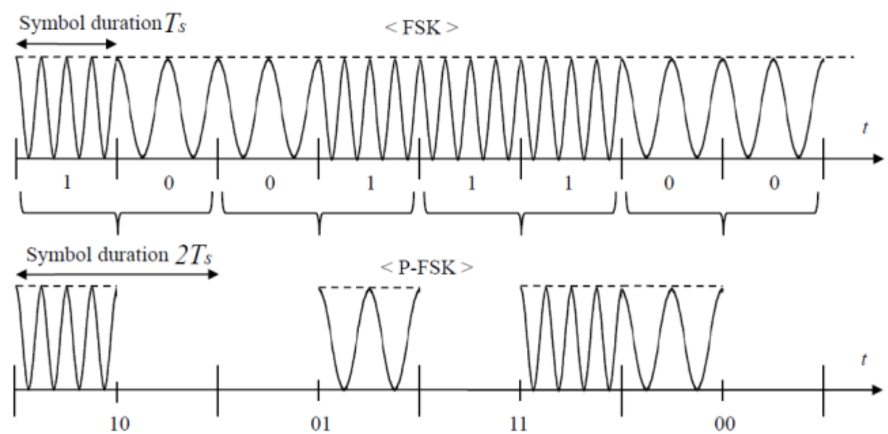
- **Motivated by reducing transmission power of FSK system that is accomplished by designing 4-dimension orthogonal signals.**
  - Higher-dimension orthogonal signals for modulation can reduce the SNR per bit required to achieve a target probability of a bit error
  - One may use the frequency-domain to obtain the high-level FSK to increase the number of dimensions.
    - ☞ Higher-level FSK occupies wider signal bandwidth.
    - ☞ High-level FSK system entails much complex receiver architecture to discriminate those increased number of frequencies.
  - To construct 4-dimension orthogonal signals without bandwidth expansion and significant increase in complexity, we propose the P-FSK here that add the time-domain orthogonality to 2-level FSK signal

Recap of P-FSK modulation(2/2)

- **Two bits are grouped together to be fed into the FSK modulator and on-off gating device to finally yield a P-FSK modulated waveform**
  - The on-off gating device is the only required hardware added to the conventional FSK transmitter
    - ☞ Its implementation overhead is negligible.
  - 4-dimension orthogonal signaling
    - ☞ 4 waveforms that indicate “00”,”01”,”10”, “11
    - ☞ Save 2.7 dB transmission power at the receiver



b_1: conveyed by the conventional FSK-modulated signal
b_0: modulated by the position.



Channel Models in TGD

- **Channel Model for Frequencies below 500 MHz**
  - For the frequency range below 500 MHz in urban areas, the COST 207 GSM Typical Urban model with 6 taps.
  - For the frequency range below 500 MHz in rural areas, the IEEE 802.22 Profile A model with 6 taps.

Table 1: COST 207 GSM Typical Urban model with 6 taps

Taps #	**Delay (µs)**	**Power in (dB)**
1	–0.2	-3.0
2	0.0	0.0
3	0.3	-2.0
4	1.4	-6.0
5	2.1	-8.0
6	4.8	-10

Table 2: IEEE 802.22 Profile A model with 6 taps

Taps #	**Delay (µs)**	**Power in (dB)**
1	0.0	0.0
2	3.0	-7.0
3	8.0	-15
4	11	-22
5	13	-24
6	21	-19

Characteristics of Channel Models

- **# of paths : 6 for each model**
  - Max. delay of IEEE802 model is larger than COST207
  - Each path contributes to performance degradation due to ISI if any kinds of counter measures are not used
    - ☞ Performance degradation would be getting worse with increasing transmission rate
    - ☞ IEEE802 channel will be more serious than COST207 channel
- **Quasi-static Rayleigh channel**
  - Due to small value of Doppler spread
    - ☞ The coefficient of each multipath remains constant over a packet transmission
    - ☞ Re-generation of channel coefficients per each packet transmission

Expectation of the performance

- **Error rate performance**
  - For low rate transmission :
    - ☞ Performance would be similar to that of single path fading channel
  - For higher rate transmission :
    - ☞ Error floor would be added to the single path fading performance due to increased ISI

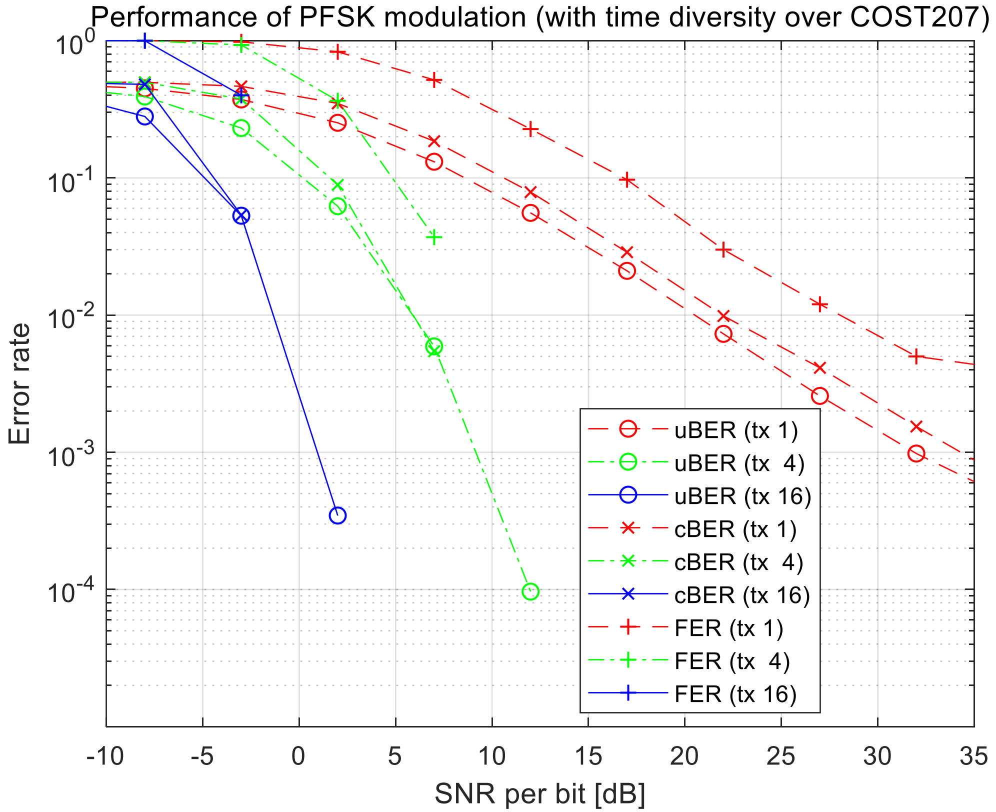
- **Approach to enhance the performance**
  - Need to achieve some form of diversity gain
  - NG-SUN FSK PHY tries to incorporate spreading to get enhanced sensitivity performance
  - If we implement the spreading in the form of multiple transmission of a packet and receiver tries to combine the demodulated symbol, we can get time diversity gain over the SNR gain

Performance evaluation with simulation

- **Simulation cases (only for P-FSK)**
  - Transmission rates : 12.5 Kbps / 50 Kbps
  - Channel model : COST207 GSM in urban area / IEEE802.22 in rural area
  - # of multiple transmission : 1 / 4 / 16
  - 1/2, K=7 convolution code
  - Hard decision Viterbi decoding
  - Interleaver-Deinterleaver
  - Total data : 200Kbits(25,000 bytes)
  - 1,000 packets of 25 byte(200 bits)/packet
- **Performance results**
  - Uncoded BER vs. Eb/No
  - Coded BER vs. Eb/No
  - PER vs. Eb/No vs. Eb/No

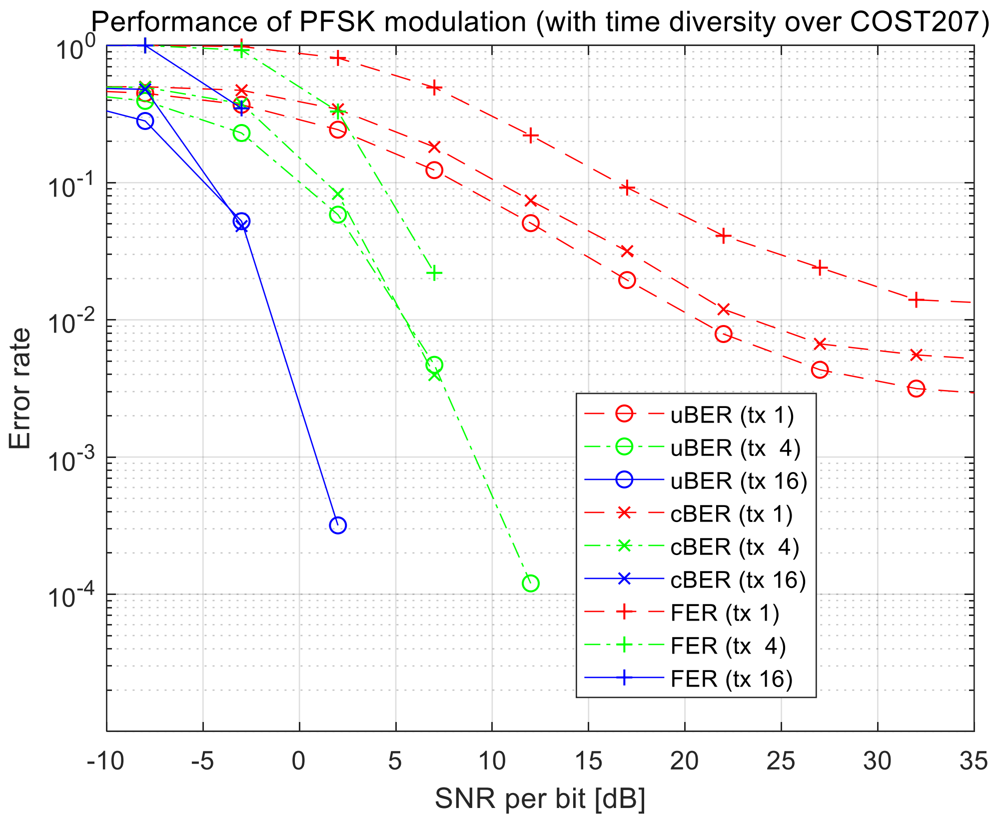
12.5 Kbps PFSK over COST207

- **1%/10% PER @**
  - Eb/No of 28/17 dB for single transmission
  - Eb/No of 9/5 dB for 4 times transmission
    - ☞ 19/12 dB gain (6 dB SNR gain + 13/6 dB diversity gain)
  - Eb/No of 2/0 dB for 16 times transmission
    - ☞ 26/17 dB gain (12 dB SNR gain + 14/5 dB diversity gain)



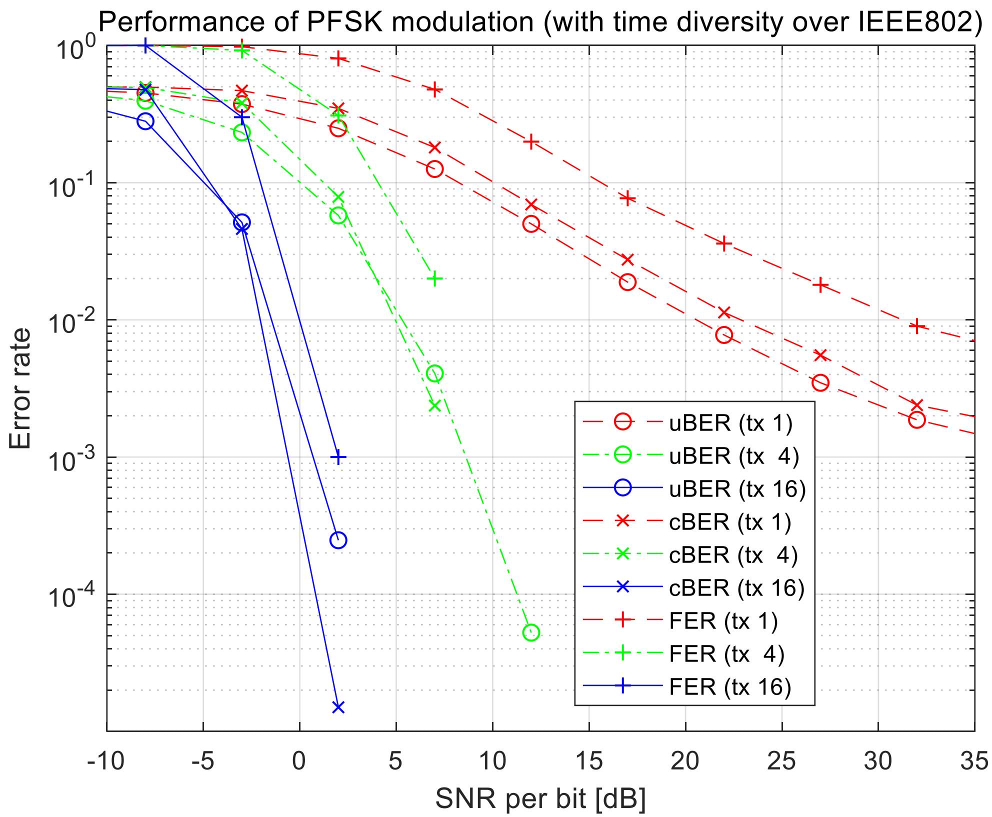
50 Kbps PFSK over COST207

- **1%/10% PER @**
  - Eb/No of ??/17 dB for single transmission
  - Eb/No of 9/4.5 dB for 4 times transmission
    - ☞ ??/12.5 dB gain (6 dB SNR gain + ??/6.5 dB diversity gain)
  - Eb/No of 1/-1 dB for 16 times transmission
    - ☞ ??/18 dB gain (12 dB SNR gain + ??/6 dB diversity gain)



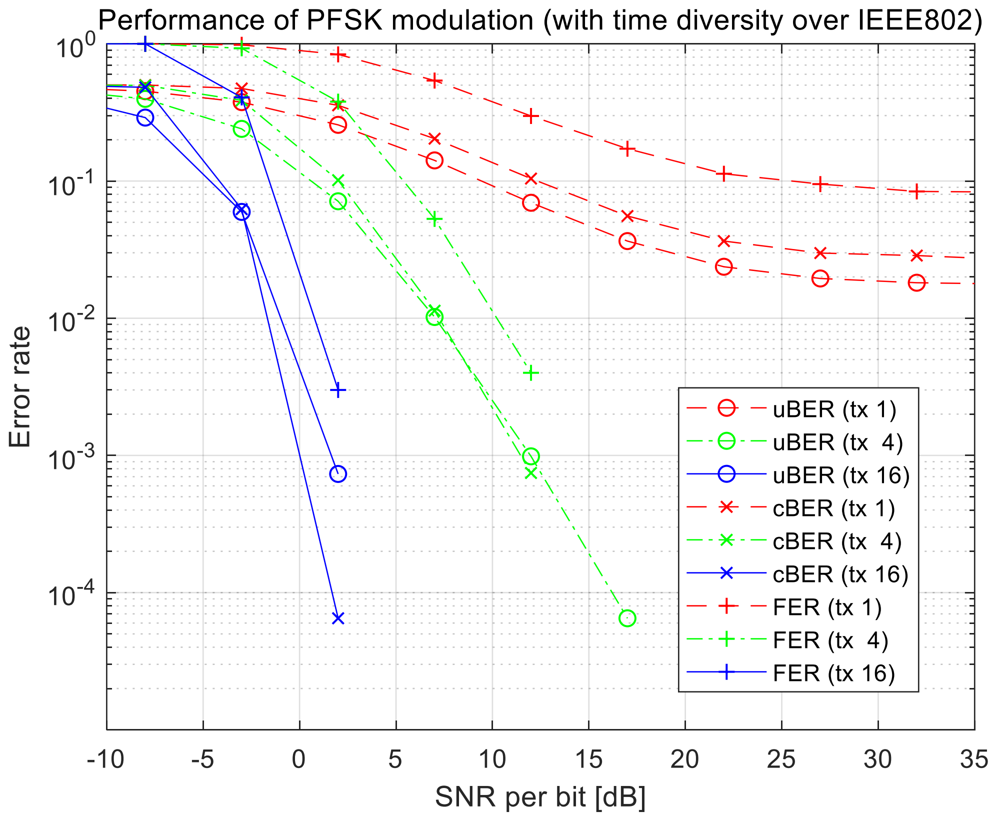
12.5 Kbps PFSK over IEEE802

- **1%/10% PER @**
  - Eb/No of 31/15 dB for single transmission
  - Eb/No of 8/4.5 dB for 4 times transmission
    - ☞ 23/10.5 dB gain (6 dB SNR gain + 17/4.5 dB diversity gain)
  - Eb/No of 0/-2 dB for 16 times transmission
    - ☞ 31/17 dB gain (12 dB SNR gain + 19/5 dB diversity gain)



50 Kbps PFSK over IEEE802

- **1%/10% PER @**
  - Eb/No of ??/25 dB for single transmission
  - Eb/No of 10/5 dB for 4 times transmission
    - ☞ ??/20 dB gain (6 dB SNR gain + ??/14 dB diversity gain)
  - Eb/No of 0.5/-2 dB for 16 times transmission
    - ☞ ??/27 dB gain (12 dB SNR gain + ??/15 dB diversity gain)



Conclusion

- **With single transmission for a packet, the error rate performance follows the single path fading and error floor as expected**
- **With multiple transmissions and receiver combining (noncoherent) of the demodulated symbols, the error rate performances show huge improvement including the SNR gain and diversity gain**

  ☞ **1% PER can be achieved even at higher transmission rates**
- **We need to consider multiple transmission as a candidate for spreading implementation to enhance the performance over multipath channel**

Thanks for Listening !
Q&A